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Next 2 Page(s) In Document Denied

I. ANNUAL REPORT No 3.

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3. Basic Studies on the Color of Pork Meat and on the Color in Pork as Influenced by Heredity, Sex, Age, Feeding and Management of Animals

4. E 21-AH-2

5. FG-Po-117

6. From January 1, 1963 to December 31, 1963.

II. SUMMARY

The determinations of pork meat color in husbandry experiments are very dificult because of uneven color on the surface of muscles section. Our results have shown that the measuring of color can be done on minced meat and the values received can be transformed into values adequate for slices. The pertinent regression equations have been given.

Pork meat color in influenced by sex of animals. The meat of gilts in comparison with that of barrows is characterized by lower content of fat, darker color and greater concentration of pigments; water-holding capacity of meat does not differ essentially.

The influence of age and live weight of pigs on the color properties of meat is pronounced. In elder animals the fat content and pigment content are higher, the water-holding capacity is worse. The differences in color consist in longer dominant wave-length and higher saturation in elder animals. The lightness of color does not change significantly in the range of age and live weight investigated. The stability of color is poorer in elder animals.

From the point of view of color and related properties of meat there seems to be no theoretical reason for preference given to elder and heavier pigs in canned meat production.

III. DETAILED REPORT

The Report was divided as in previous reports into 3 Sections i.e.

A. Determination and interpretation of color in pork meat.

B. Variability of color as influenced by various husbandry factors.

C. Metabolic factors influencing the meat color paleness in pigs.

A. DETERMINATION AND INTERPRETATION OF COLOR IN PORK MEAT

1. The influence of sample preparation on color determination

It is well known that the surface of a section even through one muscle is often very uneven in color. Consequently, great difficulties exist in measuring color of meat slices in comparative studies. Therefore, an attempt was made to study the effect of mincing the meat sample prior to color determination.

Experimental procedure

In 35 1 cm-thick slices of longiss. dorsi muscles possibly even in color, the color sttributes were determined. At the same time the slices directly adjoining to the section /i.e. of the same color/ were quickly cut up and minced twice in a meat grinder, then mixed and immediately subjected to color determination.

The determination of meat color was based on the classic method with the use of a spectrophotometer which gives data for color specification /Bouma, 1951/.

The color of slices was measured after 20 minutes cooling in the refrigerator. All determinations were made in duplicates. All operation of preparations ~~in~~ of the samples and determination of color were performed in a dark place upon meat which had been well refrigerated.

Results

Mean values received in measuring the color attributes of slices and of minced meat are shown in Table 1. In Table 2 the results of two-way analysis of variance are given.

Table 1.

Characteristics of color attributes measured in slices and in minced meat

Color attribute	Mean values		Differences
	Mince	Slices	
Lightness, %	26.32	28.43	-2.11
Dominant wavelength, mμ	587.80	587.10	+0.70
Saturation, %	23.63	21.75	+1.88

Table 2.

Analysis of variance of meat color attributes

Color attribute	Source of variation	F value
Lightness	Sample preparation	36.42^{xx}
	Meats	36.52^{xx}
Dominant wavelength	Sample preparation	1.15
	Meats	-3.42^{xx}
Saturation	Sample preparation	12.58^{xx}
	Meats	8.30^{xx}

As can be seen from the tables the determinations of dominant wavelenght in slices and in minced meat give the same results; one method of sample preparation may be used, therefore, instead of the other. In lightness and saturation of color the differences are, however, significant.

In order to see if minced meat may at all be used for the determination of lightness and saturation, the correlation coefficients between color characteristics obtained in minced meat and slices have been computed. The results are given in Table 3.

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Table 3.

Simple correlation coefficients /r/ between color attributes determined in slices and mince

Color attribute	r
Lightness	0.9392^{xx}
Saturation	0.8218^{xx}

As can be seen from Table 3 the coefficients are very high and, therefore, the deterimation of these attributes in minced meat may be applied using the corresponding regression equations.

Here they are:

Lightness, $Y = 1.12\ X - 1.13 \pm 1.97$

Saturation $Y = 0.80\ X + 2.73 \pm 2.75$

where X=values for minced meat
Y=values for slices

The above consideration leads to the conclusion that the measuring of color may be done in minced meat and that in the case of uneven color surfaces of muscle saction the results received for mince meat may be transformed into the values adequate for slices.

This possibility is of great importance for comparative studies on color in meat.

2. Meat color determination for husbandry purposes.

The results of our experiments on the methodology of pork meat color determination for husbandry purposes were elaborated and prepared for publication. This work conserns the application of a short objective method of color evaluation suitable for husbandry use especially in progeny testing station, experimental farm etc. The paper will contain the results briefly described in Annual Rep. No 2 and 3 and will be published in Journal "Roczniki Nauk Rolniczych". Three copies of the text will be sent to the Office in Rome.

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3. Pork meat color attributes as measured by the sensory test.

In order to obtain an idea of the importance of the measured color attributes /i.e. lightness, dom.wavelength and saturation/ of meat to the observer or anyone who has to evaluate meat color, we have compared meat color attributes as measured by instrument with those obtained by panel ranking the samples according to color.

Experimental procedure

The investigations were divided into two groups. In the first experiment color lightness, dominant wavelength and saturation were determined in a series of six fresh pork meat samples, with the use of instrument. Concomitantly, the 6-persons panel ranked the samples according to the color estimated by sensory tests.

In the second experiment a series of 20 fresh pork meat samples were evaluated in the same way.

The results obtained were statistically computed, the method of inference being based on the rank correlation technique.

Results

Simple rank correlation coefficients between color attributes measured by instrument and by sensoric panel rank on the six-sample series are presented in Table 4.

Table 4.

Rank correlation coefficients /r/ between color attributes measured by instrument and sensoric test ranking

Color attribute	r
Lightness	0.8857[x]
Dom. wavelength	0.6000
Saturation	0.2571

As may be seen from Table 4 the judges ranked the samples mainly according to lightness of color. The influence of dominant wavelength and saturation on the ranking was very small.

It was our feeling during this experiment that the judges were guided first of all by the factor differentiating the samples most. In this case the purposely chosen factor was a lightness and it was well perceived by the panel.

To give to the judges an opportunity to take into consideration also other color attributes we prepared the longer series consisting of 20 meat samples in a set. We tried to include into the series the samples of different tint. In this way we hoped to receive the information how far the judges were able to discern the other color attributes besides lightness.

In this way we obtained the results presented in Table 5. The further inference was based on the partial correlation technique allowing to eliminate the influence of particular factors. This computation is given in Table 6.

Table 5.

Simple correlation coefficients /r/ between ranking and color attributes.

Color attribute	r
Lightness	0.8301^{xx}
Dom. wavelength	0.7338^{xx}
Saturation	0.5474^{x}

Table 6.

Partial correlation coefficients /r'/ between ranking and color attributes

Correlated values	r'
Ranking and lightness Dom.wavelength and saturation held const.	0.5936^{xx}
Ranking and dominant wavelength Lightness and saturation held const.	0.1412
Ranking and saturation Lightness and dom.wavelength held const.	-0.2899

The tables show that though the simple correlation coefficients between ranking and all color attributes are high, the elimination of other factors leaves only the lightness as a significant one. The result is, therefore, the same as in the first experiment with the series of six samples in a set.

In this situation a new direction of these experiments is planned. In the 20 fresh pork meat samples the color attributes will be determined instrumentally. The samples of practically the same lightness will be presented to planel with the task to rank them according to tint. Afterwards, the correlation between ranking and dominant wavelength as well as saturation will be computed. With the aid of partial correlation technique we hope to find out how much these attributes are discernible to the observer.

B. VARIATION OF COLOR IN PORK AS INFLUENCED BY VARIOUS HUSBANDRY FACTORS

1. Color and related meat properties in pigs as influenced by sex

It is very well known that the carcasses of gilts contain less fat in comparison with those of barrows and are more appreciated for bacon production /McMeekan, 1940; Freeden and Lambroughton 1956; Osinska et al. 1954; 1958; Duniec and Kaczmarczyk, 1960; Stevenson et al. 1960/. It seemed of interest to check in what degree, if any, the quality of meat is controlled by sex. The opinions as to the effect of sex on meat quality especially on meat color are not consistent /Gatherum and Lawrie, 1962; Otto, 1959; Woodman et al., 1936/.

The importance of revealing these sex differences would be very great in view of its practical application in further experimental designes or in the evaluation of tested populations with unbalanced sex.

Experimental procedure

64 Large white pigs from the Progeny Testing Station, balanced for sex, belonging to 16 litters were slaughtered under standard conditions. After 48 hours' refrigeration as wholesale cuts, the loins were carved out and freed from adhering connective tissue and fat. Longiss. dorsi muscle from the region of the last six thoracic vertebrae were sampled, twice minced in a meat grinder and thoroughly mixed.

In the meat samples the following determinations were done: moisture content /by drying at 105°C after ethyl alcohol denaturation/ fat content /Soxhlet method/, total protein content /Kjeldahl procedure/, myoglobin and total pigment level /Poel, 1949/, color of meat /Janicki and Kolaczyk 1962/, water-holding capacity /WHC/ according to Pohja and Niinivaara /1957/. The WHC was expressed as a per cent of the free water out of the total moisture content of the meat /Wierbicki and Deatherage, 1958/

The results of the experiment were statistically computed with the aid of two-way analysis of variance /Snedecor, 1956/.

Results

The mean values of the properties investigated, their variations and statistical significance of the influence of sex and litters are listed in Table 7.

As it is seen from this Table the meat of gilts is characterized in comparison with that of barrows by lower content of fat, darker color and greater concentration of myoglobin and total pigment. Water-holding capacity of meat does not differ essentially.

Table 7

The mean values /$\bar{x}$/, their standard deviation /s/, coefficient of variation /C/ and variance ratio /F/ of two-way analysis of variance.

Property investigated	gilts			barrows			F value	
	$\bar{x}$	s	C	$\bar{x}$	s	C	sex	litters
Moisture, %	74,82	0.57	0.76	74.44	0.61	0.82	6.80^{x}	1.11
Fat, %	1.74	0.52	29.88	2.24	0.66	29.46	25.39^{xx}	5.50^{xx}
Protein, %	22.72	0.71	3.12	22.60	0.63	27.88	0.67	3.25^{xx}
WHC, %	38.61	3.99	10.33	39.23	4.06	10.35	0.49	2.07^{x}
Color, reflect.,%	24.64	3.28	13.31	26.81	3.74	13.99	4.53^{x}	1.11
Total pigment,mg %	83.6	12.68	15.17	73.5	13.62	18.53	12.58^{xx}	2.78^{xx}
Myoglobin$^{x/}$, mg %	67.6	9.41	13.92	61.0	11.49	18.84	5.19^{x}	3.48^{x}

x/ Myoglobin content concerns 8 litters only.

Discussion

The color of meat depends mainly on its pigment content, water-holding capacity and fat content. These factors are decisively responsible for actual meat color /Janicki and Kolaczyk, 1962/. The greatest correlation with color exhibits pigment content, after that by water-holding capacity and last, fat content.

As regards pigment content in meat as influenced by sex no data in literature are available. Our results show clearly out that gilts have greater concentration of pigments in muscles than barrows. This result is in agreement with our general picture of metabolism as related to sex.

Because the pigment content correlates very much in normal pigs with meat color it might be expected that the meat of gilts will be darker in comparison with barrows.

The differences in water-holding capacity of meat in gilts and barrows were not statistically significant in our experiment though the mean values are a little higher in gilts.

This result agrees in general with the opinions in the literature. Schön and Stosiak /1958/ did not find any difference between gilts and barrows in this respect. The same view is presented by Otto /1959/ though be sees a small tendency for better water-holding capacity in barrows' meat.

From the viewpoint of meat color the data received for water-holding capacity seem to suggest no difference in color of meat in relation to sex of pigs.

The fat content is higher in the meat of barrows. This is the result supported by data from all the literature beginning from Woodman et al. /1936/ and others. The fat present in greater quantities in meat of barrows ought to lighten the color of meat.

The direct determination of color in meat demonstrated a darker color in gilts. This is in agreement with the analysis of factors responsible for color in meat. The gilts' meat exhibit the same water-holding capacity, grater pigment content and less fat content than barrows' meat; consequently it is darker.

The data of literature on meat color as influenced by sex are very scarce. Our own computation of color scores made in Danish progeny testing stations based on a very great number of pigs showed slightly darker meat in gilts. Judge et al. /1959/ using the subjective color scoring system did not reveal any

differences in meat color in respect to sex. On the contrary, the investigations of Otto /1959/ pointed out the lighter color in gilts. Nevertheless, our results seems to be logical in the light of the analysis of factors involved in meat color formation.

2. Pork meat color in relation to age and live weight of pigs

It is well known that the production of meat is more expensive when heavier and elder pigs are used. Nevertheless, the industry prefer such meat for canned meat production especially for canned hams.

The arguments given by the industry are essentionally based on the quality of meat. But, most frequently, these arguments are not well defined and without experimental background. In general they concern such qualities as color and its stability, water-holding capacity and related meat properties. It is, therefore, of great practical importance to have at one's disposal some experimental arguments in this question.

Experimental procedure

The investigation was caried out on 36 Large White pigs /4 littermate barrows from 9 litters/ reared and fed uniformly. The pigs were slaughtered under standard conditions at 70,90,110 and 130 kg, l.w. Each weight group consisted of representatives of all respective litters.

After 48 hours' refrigeration as wholesale cuts the loins were prepared in usual manner and subjected to analysis.[x]

The analysis performed included the determinations of moisture[x], fat[x], total protein[x], myoglobin and total pigment[x], water-holding capacity /WHC/[x], soluble protein /Swift and Berman, 1960/, total soluble sulfhydryl groups in meat /Benesch et al. 1955 Sarkar and Sivaraman 1956; Bhattacharya 1958/, thermal shrinkage /Walczak, 1959/ pH /glas electrode/, color with the aid of the classic method based on the spectrophotometric curves allowing to calculate the lightness, dominant wavelength and saturation /Bouma, 1951/; stability of color /Janicki et al. 1962/ and metmyoglobin concentration on the surface of sample after 4 hours' exposure to light were also determined /Dean and Ball, 1960/.

x/ For methods see point 1 in this section

Besides chemical and physical determinations the sensory evaluation of meat was also performed. 6-person panel tested the meat samples using the standard method /Coffey, 1942/. Five units score scale was applied, "five" meaning the best grade.

The obtained results were statistically computed with the aid of analysis of variance. In addition, the relation between the investigated parameters was also analyzed by estimating the type of regression /Goulden, 1960/.

Results

Basic chemical and physiocal characteristics of meats investigated are collected in Table 8, together with significance of the differences and type of regression found. The data of sensory evaluation are listed in Table 9.

The pigs were slaughtered at 7o, 9o, 110 and 130 kg. l.w. being average 187, 212, 251 and 284 days old, respectively. The gains and food officiency were normal for the method of fattening used.

Almost all meat properties changed as the live weight and age of animals increased. Moisture content was lowered, fat content and protein content raised. Water-holding capacity was falling down, reversely, myoglobin content was increasing. Though lightness of color was not changed, dominant wavelength and saturation showed clear shifts. Stability of color changed as age and live weight increased.

Table 8.

Chemical and physical data for longiss. dorsi muscle

Characteristic investigated	Live weight at slaughter				Significance of differences	Effect		
	7o kg.	9o kg	110 kg	130 kg		Linear	Quadratic	Cubic
Moisture, %	75.00	74.20	73.20	72.80	xx	xx	-	-
Fat, %	1.63	1.97	2.40	2.73	xx	xx	-	-
Total protein /Nx6.25/, %	22.1	23.4	23.3	23.7	xx	xx	x	x
Sol.protein as per cent of total,%	36.0	34.3	31.1	31.3	xx	xx	-	-
pH	5.46	5.44	5.45	5.43	-	-	-	-
WHC,%	29.3	34.5	36.9	37.4	xx	xx	-	-
Thermal shrinkage, %	31.4	32.2	33.7	32.2	-	-	-	-
Myoglobin, mg %	68.0	77.5	86.0	111.5	xx	xx	-	-
Total pigment, mg %	98.5	105.5	115.4	148.7	xx	xx	-	-
Lightness of color, %	27.5	26.2	30.8	26.4	-	-	-	-
Dom. wavelength, mμ	584.3	586.0	588.9	588.5	x	xx	-	-
Saturation of color, %	14.6	21.8	24.0	25.1	xx	xx	x	-
Stability of color	0.16	0.37	0.44	0.32	x	-	x	-
Metmyoglobin after 4 hours' exposure to light	35.7	39.8	41.0	43.1	xx	xx	-	-
Soluble SH-groups, μM/1g tissue	6.04	5.47	4.87	5.96	-	-	-	-
Soluble SH-groups, μM/1g protein	27.3	23.5	21.0	25.1	x	-	x	-

Among the sensory properties evaluated, color, juiciness and taste intensity were shown to be affected by age and live weight /Table 9/.

Table 9.

Results of sensory evaluation of meats

Sensory characteristics	Live weights at slaughter				Signif. of differences	Effect		
	70 kg	9o kg	110 kg	13o kg		linear	qua-dra-tic	Cu-bic,
Color	4.1	4.4	4.4	4.2	x	-	xx	-
Structure	4.0	3.9	3.9	3.8	-	-	-	-
Odor intensity	4.4	4.2	4.1	4.2	-	-	-	-
Odor desirability	4.3	4.1	4.4	4.3	-	-	-	-
Tenderness	3.7	3.6	3.7	3.6	-	-	-	-
Juiciness	3.9	3.3	3.7	3.7	xx	-	xx	xx
Taste intensity	4.2	3.8	4.0	4.0	x	-	x	x
Taste desirability	4.0	3.8	4.1	3.8	-	-	-	-

Discussion

The reason for preference for heavier pigs by industry practice is based on the quality of meat. This quality is supposed to be better in elder pigs. As components of this higher quality are given mostly color and its stability, water-holding capacity, drip especially in canned meat and so no.

There are few data concerning this guestion in the literature. they will be cited when discussing the particular meat properties.

In agreement with data in the literature /Hofmann and Ritter, 1957/ the fat content in meat is significantly correlated with age and live weight. The relation is positive and regression linear. The moisture content shows, as normally, a negative correlation with fat content.

We have been told many times by practitioners that the meat of young pigs bound the water poorly. Contrary to these opinions our results showed that the higher were age and slaughter weight the worse was the water-holding capacity. The differences were highly significant.

The data in the literature are not consistent in this respect Eckart /1956/ has found no influence of age on the water-holding capacity in pigs. Heidtmann /1959/ has been able to state the existence smaller drip in heifers in comparison with elder cows. According to Schön and Stosiek / 1958/ the water-holding capacity in lighter pigs is worse than in heavier ones. It must, however, be added that the results of investigations of these authors have been collected according to trade grades of pigs and it is probable that this classification also includes the state of fatness of animals. Our own results as obtained on littermate animals are more reliable in this respect.

As regards other constituents in meat it is interesting to note that though total protein content is higher in elder pigs, the soluble protein is always lower.

The pigment content in pigs corresponds with age. This fact has been stated by Lawrie /1950/ on animals of great age differences but it has been also corroborated by us for pigs of narrow range of age. The results for myoglobin and total pigment content show essentially the same trend.

The literature data on the color of meat as influenced by age and live weight of animals are very scarce. Hofmann and Ritter /1957/ have shown the greater lightness of color in younger pigs. That is quite clear when investigating the large range of age. But the differences among groups between 70-130 kg live weight are not great and it is hardly possible to drawn any final conclusions from the data of Hofmann and Ritter because of lack of statistical computations. In our experiment we have found no significant difference in color lightness among groups.

The dominant wavelength and saturation of color increase with increasing age and live weight of pigs. No information about these color attributes have been found by us in the literature in this respect.

Stability of color decreases in elder pigs. This result is confirmed by the quicker formation of metmyoglobin on the surface of meat section after exposure of sample to light. It is worthwhile to note that parallelly with the color stability go the soluble SH-groups in muscle protein. This problem has not been undertaken by other authors.

The sensory tests have shown that the quality of meat does not depend very much on the age and live weight of pigs. Some tendency is observed for better meat in pigs slaughtered at 110 kg. l.w.

In the light of these results we do not see any theoretical reason for preference given to heavier pigs; moreover, we may

conclude that in many respects the meat of younger animals is better than that of elder ones.

Note

In order to approache to the above question of age and live weight more practically, we contacted the meat packing plant. From each pig carcass the ham was cut off and delivered to the industry for preparation of canned ham in a standard manner. After 3 months of storage the cans were opened and the meat analysed. In the canned meat the following determinations were made; jelly content, meat color and its stability /by instrument/ aroma and flavor /by panel tests/, tenderness /by shearmeter/ and juiciness /by press/.

The results are now in statistical computations and a full description of the experiment will be given in the next report.

C. METABOLIC FACTORS INFLUENCING THE MEAT COLOR PALENESS IN PIGS

It is the general opinion that the white muscle disease consists in rapid glycolysis taking place in the carcass after the death of an animal /Ludvigsen, 1954; Wismer-Pedersen, 1959; Lawrie, 1960; Briskey and Wismer-Pedersen, 1961/. Thus the meat is at a low pH and a high temperature during the first 1-2 hours post mortem under commercial conditions. It results in denaturation and aggregation of the muscle proteins /Wismer-Pedersen, 1959; Wismer-Pedersen and Briskey, 1961/ or, in other opinions, in covering muscle fibrils by a layer of denatured sarcoplasmic protein thus changing their physical properties /Bendall and Wismer-Pedersen, 1962; McLoughlin, 1963/. Consequently, a primal cause of white muscle disease is abnormally quick glycolysis in muscle.

In central point of interest are, therefore, the factors responsible for enhanced glycolysis. These factors are of various nature and ought to be investigated in connection with the determination of glycolysis.

In connection with this we have been preparing the methods of determining the glycolysis and respiration in muscle. In most cases these methods are based on the use of Warburg respirometer technique with the application of sliced tissue. We verfied many techniques suggested and have found a small adaptability of these methods for our purpose. They are not suitable for comparative studies. We have, therefore, tried minced meat in order to get more representative samples.

The results we have obtained are very good. We are now able to determine the glycolysis and respiration with a very small error.

In order to start the investigations on the white muscle disease we are preparing the animal material. We have installed the pH-meter in one of our progeny testing stations and pH is systematically determined 45 minutes post mortem in all pig carcasses of the station. The results are now in computations and we hope to have good animals for experiments in the near future.

In many cases it has been observed that in the pigs reared in the open pens the white muscle disease never appears. It seems to be a good starting point for theoretical studies of this problem.

We have prepared therefore a special experiment. Twenty eight pigs of 7 litters balanced for sex have been divided into two groups fed individually. The plane of nutrition is the same in both groups. The first group is reared in sty and the second in open pens.

Upon reaching 96 kg live weight the animals will be brought to our slaughter house, where the all pertinent determinations will be made. Besides the full set of determinations made normally in meat after 48 hours after slaughter, we shall also determine the glycolysis and respiration immediately post mortem.

The experiment is now in full course and the first slaughters are foreseen in January next year. The experiment is planned to be repeated in autumn.

Skolaczyk

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